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SMALL ELECTRICAL GENERATING PLANTS
(UP TO 100 kW)

By Ing. Marjan LESKOVAR,
Technical Counsellor
of the INGRA Trade Association,
Zagreb,
Assistant at the Institute
for Electric Power Industry, Zagreb.

Ing. Stanislav SRB,
Technical Counsellor of the INGRA
Trade Association, Zagreb

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By Ing. Marjan LESKOVAR

Technical counsellor of the INGRA trade Association, Zagreb, Assistent at the Institute for Electric Power Industry, Zagreb, and

Ing. Stanislav SRB

Technical counsellor of the INGRA Trade Association, Zagreb

I N T R O D U C T I O N

1. General remarks concerning electrification

Today electric power has become vitally important to all mankind, so that there is practically no corner of the world where electric power is not utilized to a greater or lesser extent or else efforts are not made to secure at least a supply for covering the most urgent requirements. That is the reason why so much attention is being given to the development of sources of electric power. Where it is possible to build large electric power plants an effort is made to put them into operation at the earliest possible date. This, however, cannot be achieved over a short period of time, so that the small power generating units will remain for some time the sources of electric power in many regions of the world. For this reason it is necessary to strive for the best conditions for the erection and maintenance of such small units. The rapid development of technology in this sphere has led the builders of electric plant equipment to build a very large variety of widely differing types of equipment which is one of the reasons for the relatively high prices of this equipment and for the difficulties in maintenance.

It is necessary to strive for the maximum standardization of this equipment and the proposals in this report are made with this in mind.

The countries beginning to develop electrification today will apply modern technical solutions and modern production methods, notwithstanding the fact that the structures of their economies are similar to those prevailing in the industrial countries eighty or more years ago. It follows logically that:

- under similar conditions of available natural resources, labour power and consumers, electrification will develop at a more rapid tempo than was the case in the industrially advanced countries at the beginning of their electrification;

- during the process of electrification in countries which are now beginning their industrial development, it will be possible to skip some phases of development.

These considerations will guide us when working out our proposals.

2. General reflections, limited range of application of the foreseen standardization

About fifty years ago small electric power generating plants for individual factories were still being built even in the relatively densely populated areas. Today as a result of progress made in the technique of power transmission and distribution, and of the increased scope of application of electric power, the construction of small hydroelectric power plants of up to 100 kW is out of the question in underdeveloped regions except in very sparsely populated areas and for isolated and remote small communities, which are to be found in the mountain valleys. For this reason we omit from our considerations low-head penstock generating sets with asynchronous generators which can operate only on stable frequency grids. Our attention will be limited to small independent hydroelectric power plants, with a low purchasing price and simple maintenance. Less importance will be given to the profitability of the exploitation of the available flow of water-power and to the quality of electric power service.

3. Choice of series of standardized capacity and voltage units

(a) Capacity

Standardization of power according to the standard numbers of series R5 is proposed i. e.: 10 kW, 16, 25, 40, 63 and 100 kW, for altitudes up to 1000 metres above sea level. The generators provided should be able to operate with cos fi = 0.8.

(b) Kind of current and voltage

A three-phase 50 cycle 400 V/231 V current is proposed.

4. Choice of generator

Self-exciting synchronous generators with selenium rectifiers are proposed as being the most convenient. Such generators have no exciter and consequently also no collector, and as they also do not need any voltage regulator, they are low in price, safe to operate and easy to maintain. Since they keep the voltage irrespective of the load and since their voltage grows with a climbing turn, they add to the stability of the generating set. The standardization of two speeds is proposed: 1500 and 1000 revolutions per minute which permits the utilization of these generators also for other kinds of plant.

5. Choice of water turbine

(a) Types of turbines

The ~~height of~~ head which can be attained at a given locality within the limits of economical operation and the available water flow determines the type of turbine which is the Francis turbine or the Pelton wheel or one of their combinations. Kaplan turbines cannot be taken into consideration because of their complicated design, ~~while~~ the propeller turbines ~~because of~~ the danger of cavitation during ~~the~~ operation under small loads. Because of the advantages of the Kaplan turbines when operating under heads up to 4 m, one should, however, nevertheless try to use them.

(i) To attain the low price of operations and simplicity of maintenance, preference should be given to turbines which keep the speed of rotation within narrow limits without a special governor. As such turbines usually operate with variations of speed up to ± 10 percent, the should be taken into consideration only in cases when the demand for constant frequency is not great.

Field of application: for generating sets up to 16 kW, under heads up to 6 m. They are mounted openly in the sectional chamber.

(ii) In view of the simplicity of installation, and for units operating under heads up to approximately 15 metres, turbines of the Francis type for open installation in the water chamber, without scroll case, can be taken into consideration. Field of application: for generating sets up to 100 kW.

(iii) For heads higher than approximately 15 m it will be necessary to use, in accordance with the ratio of head and flow, Francis turbines with a scroll case or Pelton wheels. For reasons of economy, only standard seamless steel penstocks with a diameter of up to 318 mm with couplings or welded joints can be used for the pressure penstocks of these small generating capacities. Heads of up to 120 m can be equipped with such pipes.

It is proposed to carry out the standardization of generating sets of the capacities P from chapter 3 (a) for the range of the heads H with the above type of pressure penstocks.

10 kW $\leq$ P $\leq$ 40 kW	13 m $\leq$ H $\leq$ 120 m
P = 63 kW	25 m $\leq$ H $\leq$ 120 m
P = 100 kW	42 m $\leq$ H $\leq$ 120 m

(b) Transmission of power

The transmission of power from the turbine to the generator will have to be effected by V-belt or by an elastic coupling.

6. Regulation and automatic devices

Standardization of equipment is proposed which would make it possible for the hydroelectric power station to operate automatically after starting, and in case of danger to the equipment to give warning signal and also to stop the plant automatically if the cause of danger is not removed in time. Such automatic devices demand only service attendance with periodical servicing and inspection.

7. Complete plants

For every type of standardized equipment several types of plants for various local terrains should be developed with simplicity of installation in view.

8. Economy of operation

It will be economically justifiable to continue the operation of such small hydroelectric power stations even after the construction of the national grid if the equipment of the small hydroelectric plant is changed to automatic operation with an asynchronous generator.

9. Final recommendations

It is recommended to finance the designing of the proposed series of standardized generating sets, equipment and plants through international technical aid.

10. General remarks - similarity of application in ships. Because of their simplicity and operational advantages among all kinds of internal combustion engines, the Diesel engines have proved to be the most efficient and suitable for generating sets so that we will deal here only with them.

The Diesel-electric generating units up to 100 kW are mostly used for two purposes:

(a) as the main source of electric power in regions where the current is not yet supplied by long-distance transmission lines;

(b) as stand-by units in cases of power failure from the grid for priority consumers for which there must be no lack of supply (hospitals, theatres etc.).

These possibilities for use affected the principles underlying the construction of the Diesel-electric generating sets. While case (a) demands a sturdy and economical construction, case (b) demands small-sized and light generating sets with a minimum of vibrations, i.e. with a higher number of revolutions.

Recent achievements have made it possible for the same engines and generators to be used for both purposes, the number of revolutions amounting in the first case to 1000 per minute and in the second case to 1500 per minute. Diesel-generating units play an important role also in ship electric power supply. The problems being identical, an attempt should be made to find common starting points for solving the problem of standardization.

11. Choice of series of standardized capacities and voltages

(a) Capacity

Owing to the great number of types of Diesel engines it should be possible to standardize a close rating of power capacities. The following standardization is proposed:

3.5, 7, 12.5, 16, 20, 25, 32, 40, 50, 60, 80, 100 kVA

Most of the world-known producers of Diesel engines have these series on their production programmes.

The power capacity depends on the operating and climatic conditions at the location.

(b) Kind of current and generator voltage

A three-phase, 50 cycle, 400 V/231 V, cos fi 0.8 current is proposed.

(c) Number of revolutions

1000 and 1500 revolutions per minute is proposed.

12. Choice of generator

As in the case of hydroelectric power generators, here also the use of a self-exciting synchronous compound generator is recommended. The construction can be standardized, but it can be modified or specially designed where special conditions are to be considered. Depending on the site of operation, a standard, special or tropical design can be adopted.

13. Choice of Diesel engine

The Diesel engine must have the qualities which are required for electric power generators, taking into account its non-uniformity and other special characteristics.

Because of their great specific weight, their volume and the higher cost of the building which they entail, slow-running Diesel engines are no longer in use in this field of power. Continuity of operation has been achieved with engines of average speeds, i.e. with 1000 and 1500 revolutions per minute. Diesel engines can be mounted on understructures or used as probable generating sets which is a great advantage in the case of gradual electrification, as it allows change in the site of operation.

As a consequence of the great number of Diesel engine manufacturers, each of whom did his best to design an engine which could be used also for other purposes (e. g. driving pumps, compressors, ships, railway engines, lorries, and tractors), the Diesel engines produced show considerable differences. This causes great difficulties in maintenance and in the training of operators. It would be a gread advantage if the producers of Diesel engines would standardize at least the main parts of the engine, for example the piston, the piston rings etc. and in this way make maintenance easier and reduce the quantity of spare parts to be kept in stock. Engine cooling is by evaporation of water or air.

The transmission of power from the Diesel engine to the electric power generator is by elastic coupling.

14. Regulating and automatic devices

Diesel generating sets for base-load requirements must be provided with synchronizing devices so as to be suitable for parallel operation with other types of power generating sets. Generating sets serving as stand-by units should operate without attendance and receive the impulses for starting the engine, exciting the generator, stopping and switching over again to supply the circuit, from the grid, automatically. Voltage, current of frequency control impulses may be used.

15. Complete plants

Projects for standardized electric power plants should be made for all chosen sizes and operating conditions. In this connection efforts should be made to standardize the additional equipment as much as possible.

16. The question of planned moving of the generating sets to new sites after they cease to be necessary.

Urgent need for electric power may require the setting up of Diesel-electric power generating plants on sites where a big hydroelectric or steam power station is already under construction. If later on it is not economically justifiable to keep the independent Diesel-electric power plant as a stand-by unit, it should be moved to a new site. Such removals of Diesel generating sets should be carried out according to schedule so as to ensure the soundest amortization of the invested capital.

SOME YUGOSLAV EXPERIENCES

17. Designs in production

(a) Hydroelectric power plants

Yugoslav enterprises manufacture standardized types of self-exciting generators as defined in point 4, self-regulating turbines as defined in point 5 (a) (i) and Francis turbines as defined in point 5 (a) (ii).

(b) Diesel-electric generating sets

The Yugoslav manufacturers of Diesel engines

mos" of Sarajevo and the manufacturers of electric power generators ~~such as~~ "Rade Končar" of Zagreb have for some time been trying to standardize the Diesel-electric generating sets and they have agreed to manufacture as standardized generating sets the following sizes:

at 1500 revolutions per minute
7, 12.5, 16, 25, 30, 40, 50, 60, 80, 100 kVA

at 1000 revolutions per minute
4.5, 12.5, 22, 25, 32, 40, 63, 75 kVA

Voltage of the generators 400/231 V, frequency 50 cycles, cos fi 0.8. Standard series construction.

18. Complete plants installed

(a) The Yugoslav industry has so far equipped 15 hydroelectric generating plants of up to 100 kW in Yugoslavia and abroad.

(b) The above mentioned types of Diesel-electric generating sets have been sold at home abroad.

BIBLIOGRAPHY

1. R.Končar Works,Catalogue 171, Small self-excited alternators,Zagreb
2. Litostroj Works, Catalogue "Open flume Francis turbines of Standard manufacture", Ljubljana
3. Invest-Import: Prospectus "Z-turbines", Beograd
4. Iron Steel Works; Export Programme of Tubes and Pipes,
5. Production programmes of Yugoslav and foreign manufactures of Diesel generating sets, Sisak.

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